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ORIGINAL ARTICLE

Does Context Affect Argument Quality and Informal Reasoning in Socio-scientific Issues?

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ABSTRACT

This research aimed to assess the quality of arguments and informal reasoning abilities of pre-service science teachers concerning various socio-scientific issues (SSI), utilizing dilemma cards. The case study method, a qualitative research approach, was employed, involving 12 pre-service science teachers. Participants completed the dilemma cards over a 12-week period. The analytical procedure for these cards incorporated content analysis. Findings from the study indicated that participants were often unable to construct a comprehensive argument that considered all argumentative components, such as claim, evidence, support, and rebuttal. While some participants displayed a modicum of success in the components of claim, evidence, and support, they typically provided insubstantial examples in the rebuttal dimension. On examining the nature of arguments based on context, it was discerned that the quality of arguments about nuclear energy differed slightly from those about other SSI. Nevertheless, context did not significantly influence the quality of arguments for 11 other socio-scientific topics. Furthermore, the study noted variations in the dimensions of informal reasoning across different SSI. It was subsequently inferred that the context might influence informal reasoning. In addition, it was observed that participants tended to focus more on the ecological dimensions of informal reasoning and less on the ethical-aesthetic dimensions. Recommendations were put forth to enhance both the quality of arguments and informal reasoning abilities.

KEYWORDS: Socio-scientific issues; argument quality; informal reasoning; pre-service science teachers; dilemma card

INTRODUCTION

In our contemporary era, rapid and continuous change profoundly influences both the scientific community and everyday life. The change influences current issues and can sometimes leave humanity in a quandary (Atasoy et al., 2022). Socio-scientific issues (SSI) encompass dilemmas and unresolved matters frequently discussed in daily life, media, and various platforms aiming to foster societal awareness and are becoming increasingly salient due to the aforementioned changes (Topçu, 2015). Examples of these issues include nuclear power plants, genetically modified organisms, organ donations, electricity theft, endangered species, and animal rights. Ke et al. (2021) believe that in the decision-making process concerning SSI, employing higher-order thinking skills to make multidimensional evaluations and informed decisions is integral to science literacy. Supporting this, Zeidler et al. (2013) emphasize that science literacy has become a catchphrase in science education. In other words, SSI can be viewed as a significant tool in promoting the skills intended to be conveyed through science literacy. The Ministry of National Education (MoNE), which views fostering science literacy as a fundamental mission, is increasingly incorporating SSI into its science curriculum (MoNE, 2018). In this context, it is believed that SSI plays a pivotal role in both imparting numerous skills to students (such as argumentation, informal reasoning, and critical thinking) and in values education, emphasizing traits like sensitivity, environmental consciousness, and responsible citizenship (Kim et al., 2020). To offer a more specific example, while SSI contributes to cognitive skills like critical thinking in students, it also focuses on values like global citizenship awareness (Chowdhury et al., 2020). Given the inherent nature of SSI, which is based on social, scientific, ethical, economic, and environmental dimensions and contains dilemmas, the process of reasoning and decision-making requires an argumentation (scientific debate) process (Namdar et al., 2019).

Forms of informal reasoning articulate the perspective from which individuals develop their arguments during the decision-making processes related to SSI (Ladachart and Ladachart, 2021) In other words, revealing the current state of informal and socio-scientific reasoning within the context of SSI is crucial. Based on the obtained results, enhancing individuals' reasoning in the context of SSI is of great importance, and the pathway to informal reasoning often involves the argumentation process (Owens et al., 2019). In this context, it is possible to assert that SSI, argumentation, and informal reasoning are intertwined concepts. This is because students, through SSI, hone their skills in argumentation, using reasoning powers, and decision-making (Topçu, 2015).

Argumentation can be defined as a written or oral process where individuals engage in mutual exchanges of ideas about the validity of a claim. It employs data, reasoning, support,

and refutations to persuade and assert one's proposition, while critically examining, debating, and reconsidering opposing claims (Berland and Reiser, 2011). SSI can serve as a context for nurturing the skill of argumentation, providing a foundation for the argumentation process. Indeed, there are studies in the literature that jointly address SSI and argumentation (Demircioğlu and Uçar, 2014; Iordanou and Constantinou, 2014; Suephatthima and Faikhamta, 2018). Many of these studies selected a specific SSI, examined argumentation skills related to that SSI, and endeavored to further develop them.

The relationship between SSI and argumentation is well documented, as is the connection between SSI and informal reasoning (Namdar et al., 2019; Owens et al., 2019). Informal reasoning is characterized as encompassing the entirety of cognitive and affective processes when deliberating on the causes and consequences, advantages, and disadvantages of complex issues (Zohar and Nemet, 2002). Given that SSI, as described above, contains multi-dimensional aspects both cognitively and affectively, including benefits and drawbacks, there are studies that address SSI and informal reasoning collectively (Atasoy et al., 2019; Liu et al., 2011; Namdar et al., 2019; Owens et al., 2019; Pope et al., 2017; Yolaçtı et al., 2022). A significant portion of these studies appears to have been conducted with pre-service teachers and middle school students.

The Significance of the Study

In the literature, several studies examine the concepts of SSI, argumentation, and informal reasoning in tandem (Akbaş and Çetin, 2018; Ladachart and Ladachart, 2021; Suephatthima and Faikhamta, 2018; Venville and Dawson, 2010). The majority of these studies focus on a single SSI or a few related SSIs. The present research, which explores 12 different SSIs, is anticipated to provide richer data insights. For quantitative research related to SSI, surveys and scales are commonly employed (Genç and Genç, 2017; Topçu, 2010), whereas qualitative studies tend to utilize scenarios (Genç and Genç, 2017). It is observed that studies using dilemma cards (Cenk, 2020; Evren Yapıcıoğlu, 2016) are limited in number. Dilemma cards not only contain scenarios but also offer choices and perspectives related to those scenarios, thereby fostering multi-dimensional thinking. In this context, the data derived from the dilemma cards chosen as the data collection tool for the present study is expected to contribute to the existing literature.

The Aim of the Study

In this study, we aimed to determine the quality of arguments and informal reasoning skills of pre-service science teachers in their 4th year of study in the Department of Science Education using dilemma cards across different SSIs. Specifically, the quality of the arguments was analyzed holistically, considering components such as claims, evidence, justification, supportive, and refutation elements. Concurrently, informal reasoning skills were assessed based on sub-dimensions, including scientific-technological, socio-economic, ecological, and ethical-aesthetic aspects. In this context, the research questions of the study are as follows:

- What is the quality of arguments presented by pre-service teachers across various socio-scientific topics?
- How do pre-service teachers demonstrate their informal reasoning skills across different socio-scientific topics?
- Do the quality of arguments and informal reasoning skills of pre-service teachers vary depending on the topic context?

METHODOLOGY

Research Method

This study was designed based on the case study approach within qualitative research methodologies. A case study offers an in-depth understanding of the situation under investigation and can serve both as the product and the subject of the research (Creswell, 2017). In this study, a holistic single-case design, a subtype of the case study, was chosen. Merriam (1998) notes that in holistic single-case studies, the examined unit (whether an individual, group, context, or program) provides comprehensive and detailed data relevant to the situation. Accordingly, this study aims to provide an in-depth exploration of a specific group's argumentative quality and informal reasoning skills across 12 different SSIs, seeking to offer a holistic picture of the phenomena under scrutiny.

Sample

This study was conducted using convenience sampling, one of the purposeful sampling methods preferred in qualitative research. The mentioned convenience sampling is chosen when the researcher has no opportunity to use other samples (Yıldırım and Şimşek, 2016). Participants included in this study are enrolled in their 4th year in the Department of Science Education. The researcher facilitates an elective course titled "Socioscientific Issues in Science Education." Twelve volunteer pre-service teachers enrolled in this course constituted the study group. These participants had not taken any other courses that directly address argumentation and SSI before this. However, they might have partially taken courses related to argumentation and SSI during the first 3 years of their undergraduate studies. For instance, during their 2nd year, they were made aware of the argumentation method in courses such as "Science Teaching I" and "Science Teaching II." Similarly, socioscientific topics were covered in courses such as "Nature of Science," "Evolution," "Biotechnology," "Environmental Education," and "Turkey's Underground and Aboveground Resources." Participants joined this study in their final term (4th year, spring semester) of the eight-term undergraduate program.

Data Collection

Within the scope of this research, dilemma cards were utilized as a data collection tool. After addressing the relevant SSI each week, participants were asked to fill out a dilemma card. Dilemma cards are instructional materials where a scenario or context is presented to the student, prompting them to make a decision related to that context (Evren Yapıcıoğlu, 2016).

To construct the dilemma cards, articles about the relevant SSI were reviewed (Evren Yapıcıoğlu, 2020; Genç and Genç, 2017; Liu et al., 2011; Namdar et al., 2019; Sakmen and Genç, 2021), alongside documents from the internet and news articles. Each dilemma card presented a context/news item or scenario related to the addressed SSI on its left side. On the right side, opinions regarding the context were listed in bullet points. Care was taken to ensure an objective and balanced distribution in both the texts on the left and the options on the right. For instance, both the negative and positive aspects of biotechnology were discussed in the text. Similarly, options supporting biotechnology, those opposing it, and neutral choices were provided on the right. Effort was made to provide as many options as possible for the participants, ensuring a comprehensive range. For instance, if eight options were given by the researcher, a ninth option titled "other" was provided to avoid limiting participants. The bottom part of the dilemma card reserved space for participants to detail their opinions and arguments, including components such as claim, evidence, supporting and refuting points. An example of a dilemma card is presented in Appendix 1.

Twelve dilemma cards were carefully prepared, considering the points mentioned above, and expert opinions (both subject matter and language educators) were sought. Based on expert feedback, certain modifications (text length, grammar, balanced distribution of options, etc.) were made. The revised dilemma cards underwent a pilot test with two volunteer pre-service teachers who were not part of the main study group. Following the pilot application, it was concluded that the dilemma cards effectively served as functional data collection tools, aptly revealing both argument quality and informal reasoning skills.

Teaching Intervention

This study was conducted within the elective course titled "Socioscientific Issues in Science Education," offered at the undergraduate level in the 4th year of the Science Teacher Education department. During the first 3 weeks of the 15-week course duration (two lecture hours each week), theoretical information about SSI, argumentation, and informal reasoning was imparted by the researcher. Subsequently, for 12 weeks, different SSIs were addressed and the argumentation process was observed. Every week, in the initial part of the lesson, the researcher presented a neutral brief on the relevant SSI, after which various methods and techniques such as drama, panel discussion, six thinking hats, and station method were employed to foster an interactive environment, also involving the participants. In other words, in the first half of the class, participants were neutrally provided with supporting domain knowledge about the relevant SSI. In the latter half, teaching techniques that they might utilize in their professional careers were demonstrated in the context of the SSI and participants were given the opportunity to experience these firsthand. Throughout this process, the researcher refrained from making personal evaluations or interpretations about the relevant SSI, ensuring participants were not unduly influenced. After holistically scrutinizing the relevant SSI in the two lecture hours mentioned above, participants individually filled out a dilemma card concerning the topic at the end of each lesson. It was deemed appropriate to fill out the dilemma cards at the conclusion of every class to prevent the variable of time from affecting the results. The socioscientific issues addressed within the scope of the research and their corresponding units in the curriculum are presented in Table 1.

As depicted in Table 1, the topics were meticulously chosen based on the subjects and learning outcomes in the Science Education Curriculum. The primary reason for this careful selection is to ensure that pre-service teachers gain experience with the issues listed in Table 1 when they encounter them in their professional careers.

Data Analysis

In the study, to determine the quality of argumentation, a scoring rubric developed by Hiğde and Aktamış (2017) was employed. These researchers devised a scoring system spanning three distinct levels (0=none, 1=weak, and 2=strong) to assess the quality of an individual's argumentation. This rubric encompasses four dimensions: claim, evidence, supportive argument, and counter-argument. The dimensions in this rubric align closely with the fundamental components presented in Toulmin's (1958) model of argumentation.

Table 1: Socioscientific issues addressed in dilemma cards

Sequence No	Relevant SSI	Corresponding Unit in the Curriculum	Grade
1	Environment/minerals	Earth's crust and its movements	4th
2	Electricity theft	Electric charges and electric energy	8th
3	Test animals	DNA and genetic code	8th
4	Recycling	Humans and environment	4th
5	Global climate change	Seasons and climate	8th
6	Nuclear power plants	Energy transformations and environmental science	8th
7	Endangered species	Humans and environment	5th
8	Genetically modified organisms	DNA and genetic code	8th
9	Hydroelectric power plants	Energy transformations and environmental science	8th
10	Biotechnology	DNA and genetic code	8th
11	Acid rain	Matter and industry	8th
12	Space pollution	Solar system and beyond	7th

To analyze informal reasoning skills in the research, the coding scheme proposed by Liu et al. (2011) was adopted. These researchers segmented the dimensions of informal reasoning into four categories: scientific-technological, socioeconomic, ecological, and ethical-aesthetic. Literature reveals studies that approach informal reasoning from a bi-dimensional or tri-dimensional perspective. However, due to the comprehensive nature of the classification provided by Liu et al. (2011), informal reasoning skills in this research were analyzed considering the aforementioned four categories based on content analysis. To demonstrate how the codes derived from participants' responses were allocated to the respective categories (themes), Table 2 was created.

In Table 2, codes were derived from the keywords present in the participants' responses. These codes were subsequently allocated under their respective themes.

In the context of validity and reliability, a primary effort was made to develop an appropriate and reliable data collection tool. During the preparation phase of the dilemma cards, expert opinion was sought. A pilot application was then conducted with two pre-service teachers. After verifying the tool's alignment with the study's objective, data collection commenced. Multiple individuals were involved in the analysis process to repeatedly review the participant responses on the dilemma cards, ensuring no misinterpretation or bias. For the data analysis in this study, assistance was sought from another researcher expert in science education and qualitative analysis (an independent scorer). According to Miles and Huberman's (1994) agreement/disagreement formula, there was an 88% concordance between the independent scorer, who examined half of the transcripts, and the primary researcher. To enhance validity, reliability, and verifiability, participant verification was also employed. Given the significance of the concepts of credibility and transferability in qualitative research, efforts were to thoroughly explain the research process to the reader to ensure credibility and transferability in the present study. In addition, exemplar responses from participants were quoted in the findings section.

Research Ethic

In adherence to research ethics, utmost diligence was applied throughout this study. Initially, the research was approved by the Social and Humanities Ethics Committee of Mersin University, as per decision number 10/05/2021-178. At the outset of the research process, participants were informed about the study's objectives and scope. It was emphasized that participation was voluntary, and informed consent forms were obtained from 12 pre-service teachers. To ensure confidentiality, participants were assigned codes such as P1 and P2. They were encouraged by the researcher to express their views on the dilemma cards candidly, without any concern for grading. Furthermore, participants were assured they could freely touch upon religious, political, cultural, or other such topics during the argumentation and informal reasoning process, if necessary. The researcher also acknowledges an ethical responsibility to the readers. To uphold this, the content of the study was described in detail, ensuring accuracy and fidelity to the data during the reporting phase.

Findings

The research findings were presented in two dimensions: argument quality and informal reasoning skills. To elucidate the argument quality, arguments from 12 dilemma cards were analyzed based on their components (claim, evidence, supportive, and refutation). Figure 1 provides a comprehensive overview of the argument components by topic.

On examining the results in Figure 1 based on the claim dimension of the arguments, it is evident that participants were able to effectively articulate their claims. In the evidence and supportive dimensions, participants demonstrated partial success. However, in the refutation dimension, their performance was notably lower.

When Figure 1 is assessed topic-wise, there is a slight increase in argument quality pertaining to the topic of nuclear energy. Nevertheless, when viewed holistically, even if the SSI topics chosen by participants varied, it can be posited that the quality

Table 2: Sample analysis table (Subject: Experimental animals)

Category (Informal reasoning dimensions)	Code	Participant statements
Scientific-technological	Scientific advancement organ production treatment methods	*I support the use of experimental animals in research. The quicker the advancements in science and technology, the faster we can progress to new inventions and treatments. For instance, the possibility of producing organs from mice excites me. (P6).*
Socio-Economic	Human-Centric	*It is more logical to conduct these experiments on animals rather than humans. There are patients in our society who eagerly await the advancements of science and hope for cures. (P1)*
Ecological	Hope Patients in Need Natural Habitat Ecological Cycle Laboratory Environment	*Experimental animals are born and die without ever experiencing their natural habitat. They lead an artificial life and are not a part of the natural cycle (P4).*
Ethical-Aesthetic	Right to Life Harming Another Being Empathy Unethical Behavior Injustice	*Just for the sake of scientific progress, we do not have the right to harm another being or deprive it of its right to life. We need to look at these animals with compassion and empathy. We are not being fair. (P11).*

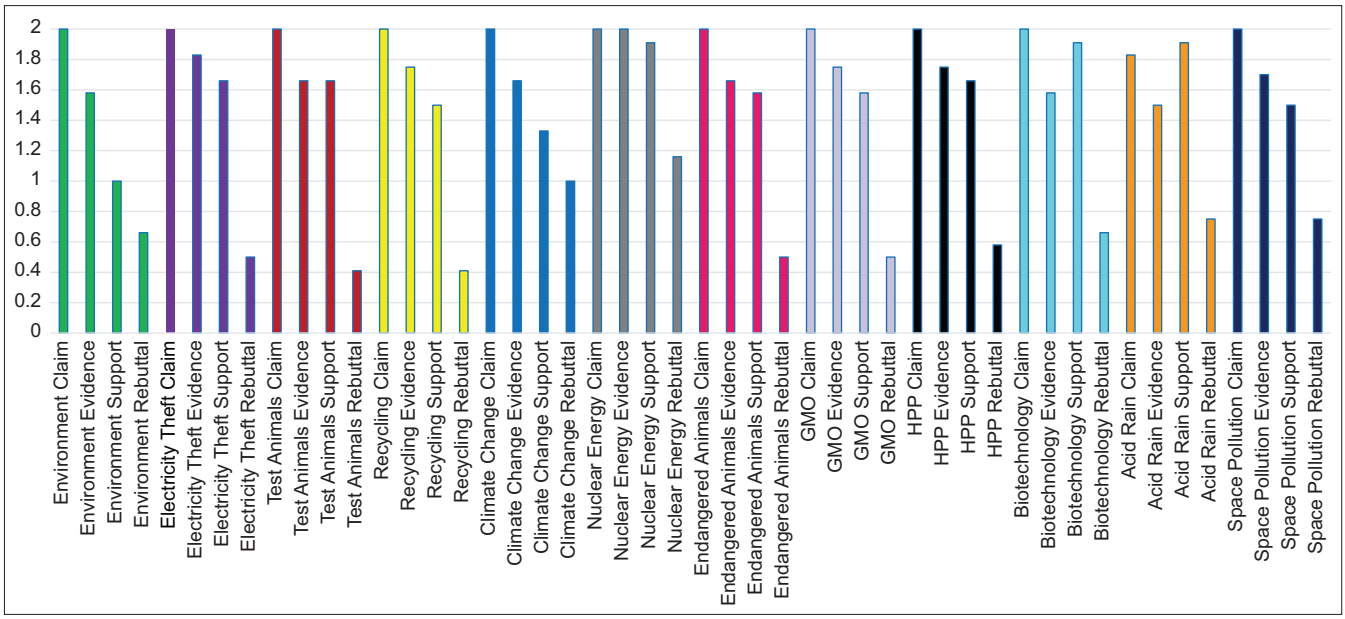

Figure 1: Argument components by subject

of the argument is not heavily influenced by the topic itself. In other words, across almost all topics, the average scores from the claim dimension to the refutation dimension appear consistent. To further examine the claim dimension of the arguments, Figure 2 was prepared.

On examining Figure 2, it is evident that participants clearly articulated their claims regarding the respective SSI. The maximum possible score for the claim dimension on the dilemma card is 2. For instance:

"Companies working on genetically modified organisms should not be supported. I believe GMOs will bring more harm than benefit to human health." (P12; Genetically Modified Organisms, Claim: 2 points)

Excluding acid rain, participants managed to achieve the maximum score in other topics. A slight drop in scores for the topic of acid rain was observed due to two participants not effectively presenting their claims. One of these participants' claims is provided below:

"Honestly, I don't have a clear idea of what measures can be taken against acid rain. Closing factories is not a solution in my opinion. We need factories for people to make a living. I am unsure whether planting trees would help. I also don't know if afforestation can occur while acid rain persists." (P11; Acid Rain, Claim: 1 point)

In Figure 3, the evidence dimension of the arguments was specifically examined.

On examining Figure 3, it can be observed that the participants scored between 1.5 and 2 points when presenting evidence related to the respective SSI. In the evidence dimension of the dilemma card, the maximum attainable score is 2 points. In general, consistent results are presented in the figure, with

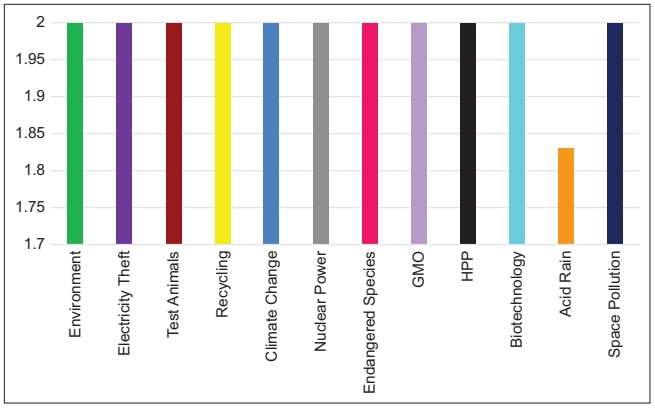

Figure 2: Argument's claim dimension by topic

the lowest average evidence score being on the topic of acid rain. Conversely, there was a slight increase in the score concerning nuclear energy. Below are example statements from participants on the quality of evidence related to the environment and nuclear energy, two of the 11 topics.

"From an environmental perspective, I would not want a mine to be established. I believe that unemployment can be reduced without harming the local population. If it is evident that mines will cause harm, alternative solutions should be sought." (P6; Environment, Evidence: 1 point).

"...During the construction of nuclear power plants, trees are cut down, and marine life is harmed. It causes radioactive pollution. Therefore, I do not support nuclear power plants. Instead, I believe we should turn to energy that is less harmful to humans and nature, namely renewable energy." (P2; Nuclear Energy, Evidence: 2 points).

In the two examples provided above, participant coded K6 presented a claim against mines and then provided ambiguous

evidence, earning a score of one point. On the other hand, the participant coded K2 stated their opinion on nuclear energy and was able to present their evidence in a more clear and specific manner, earning two points.

When evaluating Figure 3 overall and considering the scoring scale where 1 point indicates weak evidence and 2 points indicate strong evidence, it can be inferred that participants generally provided evidence of a moderate level. Figure 4 further explores the supportive dimension of the arguments.

In the supportive dimension of the dilemma card, the highest obtainable score is 2. On examination of Figure 4, it can be observed that the average scores for the supporting dimension range between 1 and 1.91. When evaluated by topic, participants appear to be relatively more successful in providing support on matters related to nuclear energy, biotechnology, and acid rains. Conversely, participants exhibited a lower performance in offering support concerning the environment. The results in Figure 4 indicate variability in the average scores participants obtained while presenting their supports for the respective SSIs.

"I don't view the establishment of HES in our country positively. HES is not our only source of energy. If we utilize renewable energy, we can meet our energy needs." (P10; Hydroelectric Power Plants, Supportive: 1 point).

"While space pollution may not pose a significant threat to us now, it is a considerable threat to future space explorations. Even though Sputnik 1 operated for only 3 weeks, it orbited the Earth for more than 2 months. Thus, there are many satellites that, having achieved their intended purpose, continue to roam aimlessly. In this context, Sputnik 1 serves as a poignant example of space pollution." (P9; Space Pollution, Supportive: 2 points).

When presenting the supportive dimension of an argument, it is anticipated that participants would utilize scientific data and fortify their claims. From this perspective, it is evident that the participant coded P10 could not provide robust support on the topic of HES, resulting in a score of 1 point. In contrast, the participant coded P9 was able to provide a more robust argument on space pollution by citing concrete and scientific examples, thus earning two points.

On analyzing the averages in Figure 5, it becomes evident that among all argument components, the refutation dimension possesses the lowest average. The highest possible score for the refutation dimension of the dilemma card is 2. Participants demonstrating their performance in the refutation dimension for the 12 SSIs have achieved scores ranging from 0.4 to 1. Below are sample responses provided by participants concerning the refutation dimension:

"No matter what is said about this, my opinion cannot be refuted. The facts are clear." (P1; Recycling, Refutation: 0 points)

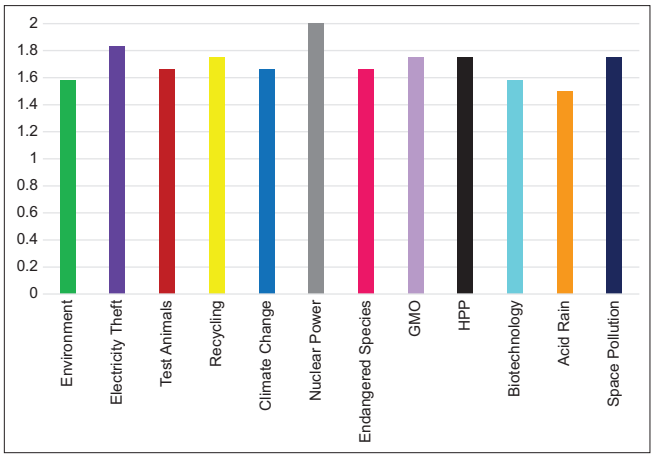

Figure 3: Argument's evidence dimension by subject

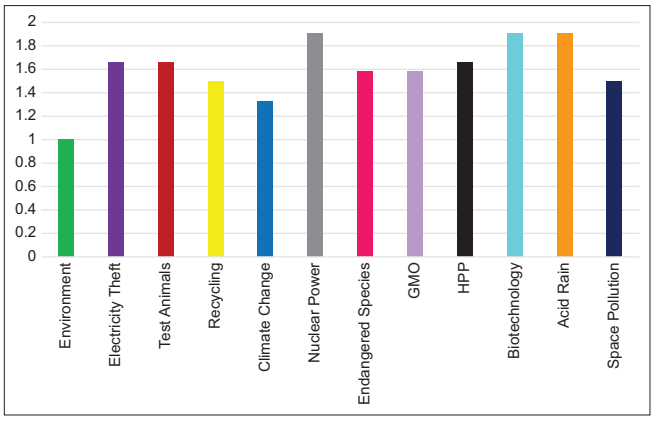

Figure 4: Argument's supportive dimension by topic

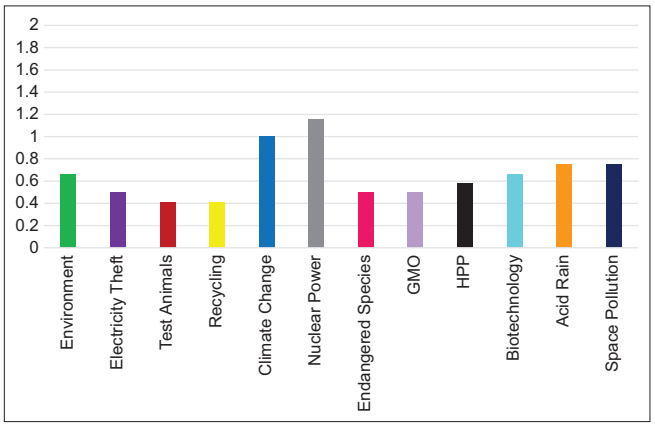

Figure 5: Argument's refutation dimension by topic

"If there are more logical and appropriate solutions to prevent the extinction of the Pirarucu fish, then my solution can be refuted. The people in the Amazon might rely on fishing as a livelihood, but to sustain the fish population, they could temporarily turn to agricultural activities. Another option mentioned the possibility of R&D efforts to sustain the fish's population. A colleague who chooses this option and speaks about the anticipated benefits of scientific studies might

persuade me. However, we must also consider that R&D might not guarantee a definitive solution in the end. Therefore, I believe imposing a ban on fishing would be the most beneficial option to mitigate the extinction risk of the Pirarucu fish." (P2; Endangered Species, Refutation: 2 points)

Participant P3, in the dilemma card addressing endangered species, elucidated the rationale behind his/her chosen view and sequentially detailed how he/she could refute alternative perspectives. Furthermore, P3 expressed a willingness to be refuted in the face of more logical and appropriate solutions. In other words, P3 demonstrated the ability to think multifacetedly while also showcasing flexibility in thought. In contrast, Participant P2 did not make an effort to refute other perspectives on recycling and failed to present clear refutations. Moreover, P2's persistence in his/her view suggests a lack of flexible thinking. Due to these reasons, while P3 received full points, P2 managed only partial points.

Revealing the participants' informal reasoning skills constitutes the secondary objective of this study. Results displaying participants' informal reasoning across 12 different SSIs were categorized and presented in Table 3.

The "religion" dimension was included in the table solely because it emerged as a distinct dimension in the context of biotechnology, as voiced by the participants. To remain true to the findings, it has been added. Below, examples of informal reasoning related to biotechnology are presented as excerpts. Displaying snippets from one single topic has been deemed suitable to observe different components of informal reasoning.

In the table, the "X" denotes the dominant opinion of participants regarding the respective SSI and their final viewpoint. On the other hand, the lowercase "x" indicates secondary points addressed within the same topic.

"Just as we expect to receive compensation for the work into which we invest our effort, it is entirely reasonable for the state to expect compensation for the electricity services provided to us. Failure to pay for these services will lead to economic challenges for the government. Electricity is one of our most essential needs, and regardless of its necessity, illicitly using it is ethically wrong." (P4; Electricity Theft, Ethical-Esthetical Reasoning; Response Chosen on the Dilemma Card: 4)

As evidenced in the excerpt above, the participant primarily focuses on the economic damage that electricity theft inflicts on the national economy. However, the participant also touches on the ethical implications of such actions. In instances like this, to ensure that both outcomes are reflected in the research without data loss, the primary emphasized point (the economic aspect) is represented with "X," while the secondary, briefly mentioned point (the ethical aspect) is denoted by "x."

"The lifespan of living beings, from birth to death, is determined by God's will. I do not find human intervention appropriate in this context. We have no jurisdiction over immortality. While we could consider cloning animals for experimental purposes, there is no necessity to exploit living beings either frivolously or in the quest for immortality. Every living being will experience death" (P1; Biotechnology, Religious Reasoning; Response Chosen on the Dilemma Card: 6)

"I support understanding past lives, grasping the universe, and the idea of infinite life. For the advancement of science and to find solutions to diseases, I back cloning. I do not believe cloning will disrupt the natural balance. For instance, had an antelope not crossed the water, it might not have fallen prey to a lion. Those interpreting events religiously might call this fate. But couldn't our creation of new species or our quest for immortality be part of our destiny?" (P7; Biotechnology, Scientific-Technological Reasoning; Response Chosen on the Dilemma Card: 2)

"I view biotechnological research and cloning for medical treatments positively, as a means to restore people's health. However, the idea of finding immortality seems quite utopian. Continuous cloning would lead to a population surge, potentially causing negative consequences, such as a country's economic collapse." (P8; Biotechnology, Socio-economic Reasoning; Response Chosen on the Dilemma Card: 8)

"To maintain the natural balance, every living entity needs to die after a certain period and complete its role in the ecological cycle. If immortality becomes a reality, we would be manipulating this natural balance. I do not believe the Earth can sustain this burden. Although I appreciate the potential benefits of cloning for treating diseases, I generally don't have a favorable view of cloning." (P5; Biotechnology, Ecological Reasoning; Response Chosen on the Dilemma Card: 5)

"Cloning might pave the way for a multitude of ethical debates, from producing homogenized humans to racism. From an ethical and legal standpoint, problems will multiply. Individual differences will diminish, leading to monotony. In addition, I doubt if Earth can bear this burden. While I see the positive aspects of cloning for medical treatments, I generally view cloning skeptically." (P11; Biotechnology, Ethical-Aesthetic Reasoning; Response Chosen on the Dilemma Card: 9)

On a general assessment of Table 3, it can be inferred that there has not been a clear and homogeneous distribution among the components of informal reasoning. In some SSI topics, sometimes two and sometimes three dimensions are prevalent. For instance, in the case of space pollution, reasoning from a scientific-technological perspective takes the forefront, while electricity theft is dominated by socio-economic reasoning. Only in the context of recycling can we say that scientific-technological, socio-economic, and ecological perspectives in informal reasoning are more evenly distributed. However, as seen in the table, ecological reasoning is often the predominant method of informal reasoning. In contrast, in the majority of the 12 SSIs (nine topics), it was concluded that ethical-aesthetic reasoning is not employed as frequently as other reasoning

Table 3: Results pertaining to informal reasoning

Socioscientific issue	Informal reasoning components*	Detailed frequency	Frequency
Environment	Scientific-technological Socio-Economic	xx	
	Ecological	XXXxx XXXXXXXXXx xxxxxxxx	3
	Ethical-Aesthetic		9
Electricity theft	Scientific-technological	XXXXXXXxx Xxxxxxxxx XXXXxxxx	
	Socio-Economic		7
	Ecological		1
	Ethical-esthetic		4
Test animals	Scientific-technological Socio-Economic	XXxxxx	
	Ecological	Xxxx	2
		xxxx XXXXXXXXXxx	1
			9
Recycling	Ethical-esthetic	XXXX	4
	Scientific-technological Socio-Economic	XXXXxxxx	4
	Ecological	XXXXxxxxx	4
	Ethical-esthetic	XXXXxxx	4
		xxx	
Climate Change	Scientific-technological Socio-Economic	xx	
	Ecological	XXXXXXxx	6
	Ethical-esthetic	XXXXXXxxxxxx	6
		xxxx	
Nuclear energy	Scientific-technological Socio-Economic	xxxxxxx	
	Ecological	XXxxxxxx	2
	Ethical-esthetic	XXXXXXXXXXx	10
		xxxxxxx	
Endangered species	Scientific-technological Socio-Economic	XXXXXXxx	6
	Ecological	XXxxxxxxxxxx	2
	Ethical-esthetic	XXXXxxxxxx	4
		xx	
Genetically modified organisms	Scientific-technological Socio-Economic	XXXxxxx	3
	Ecological	XXxxxxxxxxx	2
	Ethical-esthetic	XXxxxxx	2
		XXXXXXxxxx	5
Hydroelectric power plants	Scientific-technological Socio-Economic	xxxxxxxxx	
	Ecological	XXXxx	3
	Ethical-esthetic	XXXXXXXXXx	9
		xxxx	
Biotechnology	Scientific-technological Socio-Economic	Xxxxxxxx	1
	Ecological	XXXxxxxxxxxx	3
	Ethical-esthetic	XXXXXXXxxx	6
	Religion**	xxxxx	2
		XXxxxxxxxx	
Acid Rain	Scientific-technological Socio-Economic	xxxxxx	
	Ecological	XXXxxxxxxxxxx	3
	Ethical-esthetic	XXXXXXXXXxx	9
		xx	
Space Pollution	Scientific-technological Socio-Economic	XXXXXXXXXx	9
	Ecological	XXxxxxxxxx	2
	Ethical-esthetic	xxxx	1
		Xxxx	

**Dimensions with the highest frequency are highlighted in bold.

dimensions. However, participants are present who employ ethical-esthetic reasoning in topics such as electricity theft, experimental animals, and genetically modified organisms. In summary, while participants might not always choose based on the ethical-aesthetic component of informal reasoning in their dilemma cards, their explanations often contain statements from this perspective, indicating that the ethical-esthetic dimension is expressed secondarily.

DISCUSSION AND CONCLUSIONS

In the first sub-problem of the study, the focus was placed on the quality of the argument within different SSI contexts. Within this scope, the quality of the argument was examined across 12 distinct SSIs. It is believed that examining the argument components is a more suitable approach when addressing the quality of arguments. The initial and fundamental step in the argumentation process is for an individual to propose a viewpoint and make a claim. On examining the claim dimension of the arguments, it is evident that participants were able to articulate their claims clearly and effectively (Figure 2). To put it more explicitly, within the components of the argument, the highest average belongs to the claim dimension. Indeed, in the five-tiered chart developed by Erduran et al. (2004) to measure the quality of the argument, arguments that only consist of a claim are defined as level 1. In this context, it can be stated that making a claim during the argument-building process is relatively easier compared to forming other argument components.

On examining the evidence dimension of the arguments and basing evaluations on criteria developed by Hiğde and Aktamış (2017), it is concluded that participants demonstrate a somewhat successful performance (ranging from weak to strong, but leaning closer to strong) (Figure 3). When compared to the claim dimension, the averages indicate a slight decrease. In a study conducted by Iordanou and Constantinou (2014), it is found that participants show limited performance in presenting evidence, leading to the conclusion that their argument-building skills are also restricted. Similarly, research by Kaya et al. (2012) determined that pre-service teachers encounter difficulties in generating evidence and presenting their reasons while explaining their claims. Researchers attribute this phenomenon to a lack of clear understanding of the argument components and misinterpretation of epistemic criteria. In a study by Torun and Açıkgül Fırat (2020), it was reported that approximately 40% of the pre-service teachers make mistakes in the evidence dimension of the argument, highlighting that this particular dimension contains the most errors. Although in the present study's findings the evidence dimension is not the most error-prone, in terms of partial performance, the results align with the existing literature.

When examining the supportive dimension of the argument, partial success is observed (Figure 4). Based on the aforementioned criteria, it is determined that participants achieved partial success (ranging between weak and strong, yet leaning closer to weak). Even though the supportive dimension falls under the partial success category, its averages indicate a decline compared to the first two components of the argument (claim and evidence). Toulmin (2003) defines supporters as expressions used to reinforce the claim and evidence. From this definition, it can be inferred that proficiency in the claim and evidence is a prerequisite for having a strong supportive dimension. Furthermore, the partial adequacy of the supporters in the argument-building process could be associated with proficiency in the subject knowledge of the relevant SSI. Given that this study encompasses 12 different SSIs, competence is required across these 12 topics. Therefore, it makes sense to observe partial success in the supportive dimension. On the other hand, considering that pre-service teachers have been undergoing training in science education for 4 years and are nearing their transition to full-fledged teaching, it is expected that participants should be proficient in their subject knowledge. After all, the participants had taken courses related to some of the SSIs addressed in this study (Biotechnology, Renewable Energy Resources, Environmental Education, etc.) before the research process.

On examining the rebuttal dimension of the argument, it is observed that this dimension possesses the lowest average among the argument constituents (Figure 5). Considering that participants generally scored between 0.4 and 1 point (weak) in the rebuttal dimension, it can be stated that the rebuttal falls into a sub-weak category. Bağ and Çalık (2017) highlighted the challenges faced when constructing a rebuttal within an argument. Similarly, research conducted by Jiménez-Aleixandre et al. (2000) on genetics provided numerical results that echo these challenges. In their study, the argument components consisted of 66% claim, 21% evidence, and 10% support, while the rebuttal component was almost non-existent. A study by Cenk and Ercan Yalman (2022) concluded that pre-service teachers were inadequate in presenting rebuttals. Both the findings of the present study and those from the literature suggest that the low performance in the rebuttal dimension can be explained using Toulmin's (2003) classification of argument components. Toulmin (1958), while examining argument structure, identified claim, evidence, and support as primary components, and added dimensions such as qualifiers and rebuttals for advanced and complex arguments. Based on this classification, it is plausible to suggest that the rebuttal is the most challenging dimension within an argument structure. Various researchers analyzing argument quality (e.g., Erduran et al., 2004; Lin and Mintzes, 2010; Venville and Dawson, 2010) consider different classifications and criteria. However, regardless of the classification adopted, the presence of rebuttals in scales and rubrics elevates an argument to the highest qualitative level. From this perspective, constructing an argument with a rebuttal is perceived as a skill not every individual possesses.

In addressing the study's second sub-question, the focus was on whether participants' informal reasoning varied across different SSIs. The results of the present study revealed a clear and heterogeneous distribution among the dimensions of informal reasoning (scientific-technological, socio-economic, ecological, and ethical-esthetic) (Table 3). Put differently, as the SSI varied, so did the dimensions of informal reasoning (as seen in Table 3 and the quotes related to electricity theft in the findings). The presence of diverse combinations might explain the aforementioned heterogeneous distribution. For instance, while ecological and socio-economic reasoning are evident in the context of climate change, ethical-esthetic and

scientific-technological reasonings are observed regarding GMOs. Aligning with these findings, Yolaçtı Kızılkaya and Öztürk (2022) stated that pre-service teachers' forms of informal reasoning varied based on scenarios. In a study by Atasoy et al. (2019), students' levels of informal reasoning were examined using three different SSI contexts and various positions. When students assumed roles such as businessperson, environmentalist, or government representative, changes in their reasoning levels were observed. Linking this phenomenon with the complex nature of SSI, Zohar and Nemet (2002) emphasized that informal reasoning necessitates a holistic viewpoint, requiring detailed consideration of pros and cons as well as cause and effect when making decisions. Consequently, the presence of such multiple, combined viewpoints, and heterogeneous distribution is both an expected and desired outcome. However, in contrast to the present study's results, Liu et al. (2011) found that approximately half of the university students approached informal reasoning from a single perspective and lacked a multifaceted viewpoint.

This research also encountered an undesirable result. In the majority of the 12 SSIs (nine topics), it was found that informal reasoning from an ethical-esthetic standpoint was not as frequently conducted as other dimensions of reasoning. Yet, the ethical-esthetic dimension is considered secondary by participants during the informal reasoning process. Consistent with this study's findings, Liu et al. (2011) also reported that university students, when informally reasoning within an environmental SSI context, least often examined from an ethical-esthetic perspective.

Unlike other SSIs, it was observed that while completing the dilemma card related to cloning within the scope of biotechnology, participants included statements related to the religious dimension. This finding is consistent with several studies (Evren Yapıcıoğlu, 2016; Halverson et al., 2009; Pope et al., 2017). For instance, in the study conducted by Halverson et al. (2009), they examined the patterns of informal reasoning university students exhibited when making decisions about stem cells. The study found that participants made decisions from eight different perspectives, with one of those perspectives being religious. Similarly, Pope et al. (2017) compared the informal reasoning levels of devout Christian youths with those of non-religious and non-Christian youths on biotechnology topics. The results indicated that devout Christian youths displayed fewer scientific reasonings. Zeidler et al. (2013) posited that in the informal reasoning process related to SSIs, while scientific principles and data can be utilized, one might also be influenced by various non-scientific factors. The researchers listed these factors as personal experiences, politics, economics, ethics, and religion. In this context, it is believed that encountering a religious dimension in informal reasoning about certain SSIs should be naturally accepted.

In the third focus of the study, the relationship between the topic context, argument quality, and informal reasoning was explored. When considering the quality of arguments within the topic context, it was observed that participants could form slightly more qualified arguments on the topic of nuclear energy (Figure 1). This situation could be related to the geographic location of the participants. The data for this research was collected in Mersin, and it was observed in classroom discussions that participants had advanced knowledge regarding the nuclear power plant under construction in the Akkuyu region of Mersin and offered various solutions. Indeed, the quality of arguments in the dilemma card related to nuclear energy was somewhat better. While Walker and Zeidler (2007) argued that environmental factors could influence decision-making and argument formation, similarly, Wiyarsi and Çalık (2019) suggested that the geography and context from which data were sourced in SSIs could affect study results. At this point, it could be said that the justification the researcher put forward aligned with the views of other scholars. As mentioned earlier, the researcher observed the participants' subject knowledge only in classroom discussions. In most studies in the literature, only a single SSI context was considered, so there were data collection tools measuring the knowledge level about the relevant SSI. However, a distinctive feature of this study, compared to many in the literature on SSIs, was its inclusion of multiple SSI contexts. Therefore, there is not a data collection tool measuring knowledge level separately for each SSI. Consequently, there were no numerical results presenting a comparative knowledge level of participants for each SSI.

As the content of SSI varies, numerous researchers have pointed out that the quality of arguments constructed by pre-service teachers also varies, and that the quality of arguments can increase over time (Cenk and Ercan Yalman, 2022; Demircioğlu and Uçar, 2014; Lee and Grace, 2012). In this context, Torun and Açıkgül Fırat (2020) regard receiving education supported by argumentation as the most significant factor influencing the level of argumentation. Similarly, according to Erduran et al. (2004), it is crucial to provide participants with information about argument quality before argumentation to clearly present the quality of their arguments. At the beginning of this research, participants were informed for 3 weeks about SSI and the argumentation process. In subsequent weeks, an SSI was discussed in the classroom environment every week, and after the instruction, participants were asked to fill out a dilemma card on the relevant topic. Considering the research process, it can be said that no direct and continuous intervention was made to enhance the participants' argumentation skills. Another statement suggests that the lack of significant change in argument quality over time might be due to not providing training on argumentation development during the 15-week period. In a similar study conducted by Cenk (2020), nine different SSIs were addressed with pre-service teachers over 9 weeks, and it was concluded that there was not a consistent increase in the level of argumentation over time. The lack of improvement in argument quality in the mentioned study is linked to the absence of argumentation training during the research process. Moreover,

when considering that the argumentation process may be influenced by emotional, ethnic, social, religious, political, and environmental factors, it is suggested that such change can be time-consuming and challenging. On the other hand, studies yielding different results from the present research findings (Karışan, 2011) state that even without instruction, as participants' experience in argumentation increases, the quality of argumentation can also improve. Although the current research did not observe a progression in argument quality over time, studies in the literature (Akbaş and Çetin, 2018; Suephatthima and Faikhamta, 2018) indicate that with appropriate instruction, the quality of arguments can improve over time.

When the main focus points of the research are generally summarized, the present study investigates the argument quality and informal reasoning skills of pre-service teachers in different SSI contexts. The primary objective of the research is to determine whether these skills are influenced by the subject context. In line with this purpose, the results obtained indicate that the quality of arguments among pre-service teachers is somewhat adequate, and performance gradually decreases from the claim dimension to the refutation dimension in 12 different SSI contexts. In this context, it can be concluded that there is a need to improve the quality of the argument. In terms of informal reasoning, it is observed that pre-service teachers can holistically examine the SSI and can display multiple perspectives. However, it can be said that the ethical-aesthetic dimension remains in the background compared to other dimensions when engaging in informal reasoning.

Drawing from the research results, a general assessment suggests that the SSI context does not have a pronounced impact on argument quality. Nevertheless, it can be posited that the dimensions of informal reasoning vary depending on the context within different SSIs. Moreover, it is reasonable to argue that dilemma cards are effective data collection tools in revealing outcomes related to argument quality and informal reasoning. At this juncture, it would be advisable for researchers to conduct studies that test the functionality of current and diverse techniques, such as dilemma cards.

In this study, due to the inability to prepare 12 different subject knowledge tests for 12 distinct SSIs, the relationship between subject knowledge and argument quality was not examined. For researchers interested in exploring the connection between subject knowledge and argument quality, it is believed that the aforementioned situation could serve as a potential research topic, and it is thus recommended for further investigation.

On examining the argument quality in the study, it can be stated that the pre-service teachers did not achieve the desired level in the refutation dimension. In this context, it may be advisable to increase in-class activities where participants can experience the argumentation process. If possible, introducing or expanding elective courses focused on argumentation and SSIs in education faculties could be considered as a recommendation.

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Appendix

Appendix 1: Example of dilemma card (biotechnology)

In biotechnology research, cloning applications are included for therapeutic purposes and to facilitate life. Researchers believe that by replicating living organisms using various methods, they can address numerous challenges. One such method involves cloning endangered and nearly extinct species.

In a project from Australia, the goal is to clone the 'Tasmanian Tiger' from a sample preserved in an alcohol bottle for 153 years. Another research group aims to clone a mammoth using a 20,000-year-old tissue sample found in the Siberian glaciers. The British newspaper, The Independent, reported that British scientists intend to preserve the rhino's genes by combining the animal's skin cells with the embryos of its close cousin, the southern white rhino. It is noted that the resulting creature will be a hybrid of the cells from both subspecies. Scientists are hopeful that the offspring will produce the sperm and eggs of the northern white rhino. There are speculations that creatures created as a result of cloning might offer solutions to numerous diseases, and that extinct plants might be cloned for use in the treatment of various ailments. Some even suggest that this method might eventually unlock the secret to immortality. (The Times, 2021)

Based on the aforementioned news article, how do you believe research in the field of biotechnology will impact humanity and the global order?

1. There will likely be a positive impact. I would desire the reintroduction of extinct or endangered species to our planet.
2. A positive effect is anticipated. Advancements in biotechnological research might open the door to potential immortality.
3. There will be a beneficial impact. It represents a significant step forward in the treatment of diseases.
4. The implications could be negative. Creating new combinations and hybrid species would mean manipulating the natural order artificially.
5. The effect is expected to be adverse. For the maintenance of ecological balance, every organism must complete its lifecycle and fulfill its role in the ecological cycle. The Earth might not sustain the burden of immortality.
6. A negative outcome is anticipated. The lifespan of creatures, encompassing both birth and death, lies within divine will. I don't find human interference appropriate.
7. I am ambivalent. While I see the potential positive effect for endangered species, I have reservations regarding the prospect of immortality.
8. My perspective is mixed. I view the advancements in disease treatment positively, but I'm skeptical about achieving immortality.
9. Other considerations ……